JIMO Subsurface Science Subgroup

Our Starting Point (NRC Decadal Survey – for Europa)

Relevant Group 1 Objectives:

- Characterize the three-dimensional distribution of any subsurface liquid water and its overlying ice layer.
- Understand the formation of surface features, including sites of recent or current activity.
- Identify candidate landing sites.

Relevant Group 2 Objectives:

- Characterize the surface composition, especially compounds of interest to prebiotic chemistry.
- Map the distribution of important constituents on the surface.

Our Draft Science Objectives

(D. Blankenship, B. Campbell, R. Poppalardo, D. Sandwell)
(assisted by: N. Makris, F. Nimmo, L. Proctor, D. Winebrenner)

Objective I: To determine the volumetric distribution of free water (including brines) within Europa, Ganymede and Callisto.

Objective II: To determine the means of ice-ocean interchange of material on Europa and where this material could best be sampled by future landed missions.

Objective III: To determine the geological processes that control the exchange of material in the shallow subsurface (above the annealing depth) of Europa, Ganymede and Callisto.

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<u>Draft Investigations</u>

Objective I: To determine the volumetric distribution of free water (including brines) within Europa, Ganymede and Callisto.

- **Investigation A: Study the subsurface thermokinematic factors that control the distribution of free water and how this distribution has changed through time.**
- **Investigation B: Study the relationship between these thermokinematic factors and observed surface features.**

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Draft Investigations (cont.)

Objective II: To determine the means of ice-ocean interchange of material on Europa and where this material could best be sampled by future landed missions.

- Investigation A: Test the hypothesis of direct exchange between any ocean and the icy mantle's cold brittle shell and establish whether there is any direct means for ice-ocean interchange with the shallow subsurface.
- Investigation B: Test the hypothesis of indirect exchange with any ocean through the movement of deep ductile ice into the cold brittle shell.

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Draft Investigations (cont.)

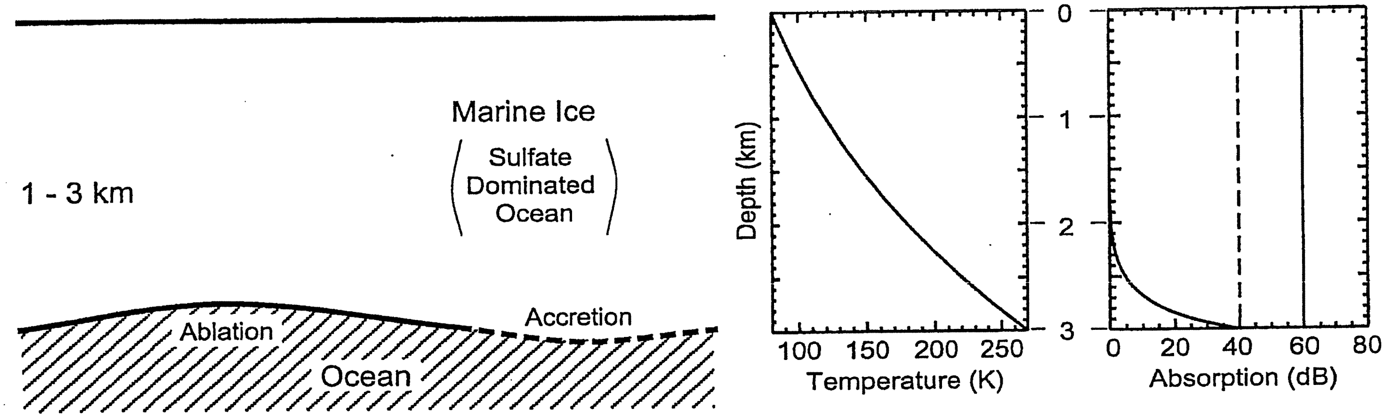
Objective III: To determine the geological processes that control the exchange of material in the shallow subsurface (above the annealing depth) of Europa, Ganymede and Callisto.

- **Investigation A: Study the structure with depth in the shallow subsurface and its relationship to the mapped distributions of surface constituents, physical structures and thermal features.**
- **Investigation B: Study the relationship between the geological processes that operate beneath the regolith and the thickness of the shallow subsurface.**

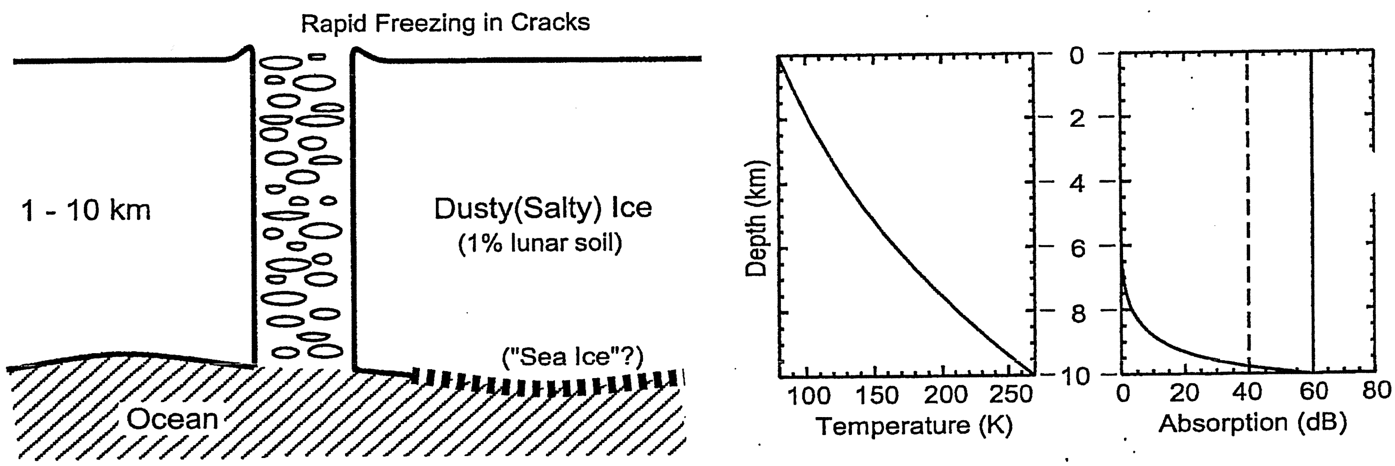
Radar Sounding Models for Competing Europan Thermokinematic and Ice-Ocean Interchange Hypotheses

(note thermal, compositional and structural horizons)

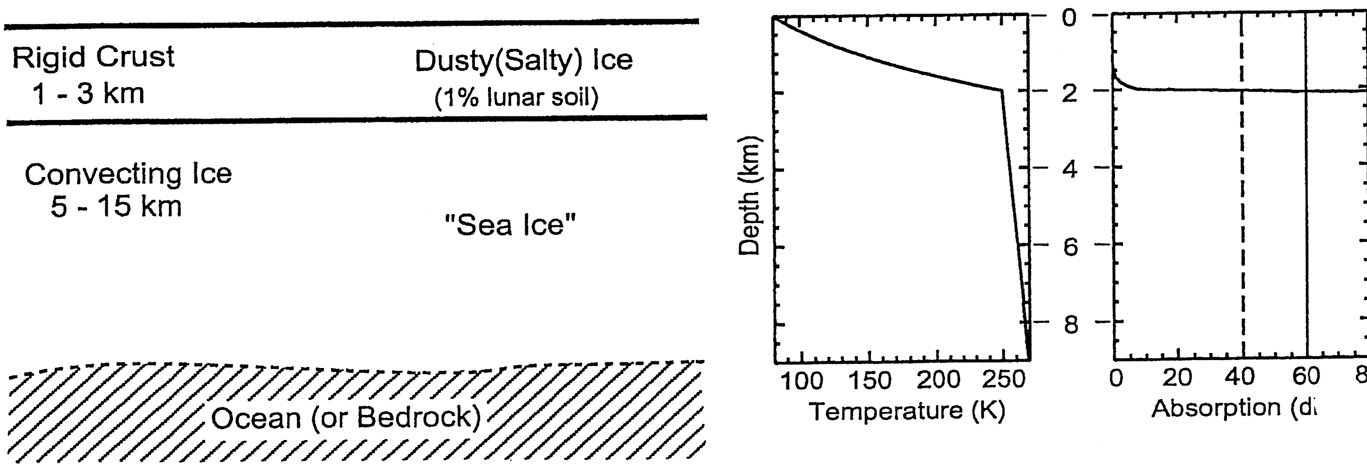
A) Marine Ice Processes



B) Tidal/Tectonic Processes



C) Convection Processes



Blankenship et al., ERSIDT Report (1999);
Moore, Icarus (2000).

Measurements:
Global to Regional Electromagnetic Horizons

Interface / moon **C – Callisto** **G – Ganymede** **E – Europa**	**Minimum requirement** **~ z (min – max)**	**(type of horizon)** **Comments**
Lag / regolith base C – G – E	1 – 100 m	(compositional / structural) mappable
Annealing zone C – G – E	10 – 100 m	(structural) mappable
Brittle / ductile transition C? – G – E	2 – 30 km	(thermal / compositional ?) profiles
Accretionary ice – E	2 – 20 km	(compositional / structural) profiles
Ice / ocean interface – E	2 – 20 km	(compositional / thermal) profiles

Note: minimum horizontal resolution <z> / 5
minumum horizontal resolution <z> / 50

Measurements:

Topography Requirements for the Jupiter Icy Moons Orbiter

Subsurface and Remote Sensing Groups, June 10, 2003

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The basic processes that generate and support topography are:

1) **<u>Mass wasting</u> – This includes slides generated by oversteepened topography.**
2) **<u>Cratering</u> – Topography generated by impact craters at all scales and the subsequent flows, mass wasting, and isostatic response that modify the crater topography.**
3) **<u>Fracture and Chaos</u> – This includes topography generated by brittle fracture, and other shallow processes where stress is confined to the surface. Also "ice raft" topography.**
4) **<u>Cryolcanism</u> – Topography generated by cryovolcanic ejecta and flows.**
5) **<u>Bands and Grooves</u> – This includes topography generated by tectonics and support of topography by the overall strength of the lithosphere (brittle and ductile).**
6) **<u>Flexure and folds</u> – This includes support of topography at the flexural wavelength.**
7) **<u>Porosity</u> – Topography that is isostatically compensated by laterial density variations due to variations in the porosity of the ice.**
8) **<u>Chemical isostasy</u> – This includes density variations, mostly in the brittle shell, due to lateral variations in composition. For example, variations in salt content of the ice can cause topography. If the salt is contained within brine pockets, such variations should lead to lateral variations in electrical conductivity.**
9) **<u>Thermal isostasy</u> – This includes density variations in the lower ductile layer due to lateral temperature variations from solid-state convection and plumes.**

(Sandwell, Nimmo and Poppalardo, in prep.)

Note that all are associated with thermal, compositional, and structural horizons.

Measurements:

Topography Requirements for the Jupiter Icy Moons Orbiter

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Table 1. Topographic features and proposed requirements

Feature / moon C – Callisto G – Ganymede E – Europa	Reference	Minimum requirement (m) H	 V	Comments
Strength-dominated Impact craters	Melosh [1989]	30	5?	2-D coverage Long λ accuracy not required
Craters C – G – E				
Band fault scarps – E	Proctor et al., 2002	15	15	1-D profiles
Chaotic terrain – E		30	10	2-D coverage of small areas
Band topography – E	Greenburg and Geissler, 2002; Proctor et al., 2002	100	50	1-D profiles; Long λ accuracy is required
Grooved Terrain – G	Giese et al., 1998	200	60	Long λ accuracy is required
Rift – G	Nimmo et al. 2002.	1000	125	
Flexure – E	Figueredo et al., 2002; Nimmo (personal)	500	10	Long λ accuracy is required; Some 2-D coverage
Double ridge – E		500	65	
Mitten – E	Figueredo et al., 2002	1000	20	Long λ accuracy is required
Compositional convection – E	Nimmo et al., (Icarus, in review)	200	10	Long λ accuracy is required
Thermal convection – E	Showman and Han, 2003	200	10	Long λ accuracy is required

Note that sampling of associated EM horizons requires less (5 – 10 X) horizontal and vertical resolution.